Low resolution spectroscopy of hot post-AGB candidates II. LS, LSS, LSE stars and additional IRAS sources*

Mudumba Parthasarathy,[1,2,3] John S. Drilling,[4]
J. Vijapurkar,[5] and Yoichi Takeda[1]

[1] *National Astronomical Observatory of Japan (NAOJ)*
2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
m-partha@hotmail.com

[2] *McDonnell Center for the Space Sciences, Department of Physics,*
Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130, USA

[3] *Aryabhatta Research Institute of Observational Sciences,*
Nainital, 263129, India

[4] *Department of Physics and Astronomy, Louisiana State University,*
Baton Rouge, Louisiana 70803, USA

[5] *Homi Bhabha Center for Science Education, Tata Institute for Fundamental Research,*
V.N. Purav Marg, Mankhurd, Mumbai 400088, India

(Received ; accepted)

Abstract

Hot (OB) post-AGB stars are immediate progenitors of planetary nebulae (PNe). Very few hot post-AGB stars are known. Detecting new hot post-AGB candidates and follow-up multiwavelength studies will enable us to further understand the processes during the post-AGB evolution that lead to the formation of PNe. Case-Hamburg OB star surveys and their extension (LS, LSS, and LSE catalogues) and IRAS (point source) catalogues are good sources for detecting new hot post-AGB candidates from low resolution spectroscopy. Spectral types are determined from low resolution optical spectra of 44 stars selected from the LS, LSS, and LSE catalogues. Unlike the stars in the first paper, the stars in this paper were selected using criteria other than positional coincidence with an IRAS source with far IR (IRAS) colours similar to post-AGB supergiants and planetary nebulae. These included high galactic latitude, spectral types of O, B, A supergiants, emission lines in the spectrum and known spectral peculiarity. From the present study we find that LSS 1179, LSS 1222, LSS 1256, LSS 1276, LSS 1341, LSS 1394, LSS 2241, LSS 2429, LSS 4560, LSE 16, LSE 31, LSE 42, and LSE 67 to be new hot post-AGB candidates. Further study of these candidates is needed.

Key words: stars: AGB and post-AGB — stars: evolution — stars : early-type

— stars: emission-line — stars: classification — stars: atmospheres

1. Introduction

From an analysis of the IRAS point source catalogue data, several post-asymptotic giant branch (post-AGB) candidates were detected (Parthasarathy & Pottasch 1986; Parthasarathy & Pottasch 1989; Pottasch & Parthasarathy 1988; Parthasarathy 1993; Kwok 1993; Van Winckel 2003). These stars have far-infrared (IRAS) colours similar to proto-planetary nebulae (PPNe) and planetary nebulae (PNe) (van der Veen & Habing 1988; Pottasch et al. 1988). Several of them are at high galactic latitude, like HD 161796 (F3Ib) (Parthasarathy & Pottasch 1986) and LS II + 34 26 (B1Iae) (Parthasarathy 1993). Multiwavelength studies of these objects by several investigators have confirmed that these are indeed in post-AGB stage of evolution (Kwok 1993; Van Winckel 2003). The post-AGB stars seem to form an evolutionary sequence (K, G, F, A to OB supergiant types) in the transition region from the tip of the AGB to the early stages of planetary nebulae (Parthasarathy 1993; Parthasarathy et al. 1993). In order to understand the evolution from cooler to hotter post-AGB types and then into the young PN stage, it is important to detect and study several hot post-AGB candidates. Vijapurkar et al. (1997); Vijapurkar et al. (1998) and Parthasarathy et al. (2000) presented the results of low resolution blue spectra of 40 IRAS sources with far-IR colours similar to PNe and PPNe (van der Veen & Habing 1988; Pottasch et al. 1988). A few of these objects have shown rapid changes in MK spectral type (Parthasarathy et al. 1993; Parthasarathy et al. 1995).

The importance of the detection of new hot post-AGB candidates relies in objects such as SAO 244567 (Hen 3-1357) and LS II +34 26. SAO 244567 evolved rapidly from a B-type post-AGB star into a young PN within a period of 20 years (Parthasarathy et al. 1993; Parthasarathy et al. 1995; Bobrowsky et al. 1998). The variations in the spectrum of SAO 244567 were dramatic. Another star LS II +34 26 initially classified as a massive B supergiant (Turner & Drilling 1984) turned out to be a rapidly evolving B-type post-AGB star (Parthasarathy et al. 1993; Smith & Lambert 1994; Garcia-Lario et al. 1997). Other such object are LSE 162 (SAO 85766) (Volk & Kwok 1989; Arkhipova et al. 2007) (references therein) and LSIV -12 111 (Conlon et al. 1993). Another reason to detect more hot post-AGB candidates is their abundance peculiarities (McCausland et al. 1992) which are different when compared with the chemical composition of cooler post-AGB stars (Van Winckel 2003). Very few hot post-AGB stars are known and most of them are at high galactic latitudes and several of them are not IRAS sources (McCausland et al. 1992; Moehler & Heber 1998). We started a program to identify new hot post-AGB candidates by obtaining spectra of selected stars from LS, LSS and LSE catalogues (Hardrop et al. 1959; Stephenson & Sanduleak 1971; Drilling 1994; Drilling

* Based on observations obtained at the Cerro Tololo Inter-American Observatory (CTIO), Chile.

& Bergeron 1995), in the hope that some of them would reveal their post-AGB nature by variations in the spectrum. And, if we have a siginificant sample of hot post-AGB candidates subsequent chemical composition study of these candidates may enable us to understand their abundance peculiarities. LS, LSS and LSE catalogues are best sources for selecting high latitude luminous hot stars. In this paper we present new spectral types for 44 of these stars based on observations made with the 1m telescope of the Cerro Tololo Inter-American Observatory (CTIO), Chile. Included are several IRAS point sources which were not included in the first paper (Parthasarathy et al. 2000).

2. Selection criteria

The observing list consisted of stars selected from the LS, LSS, and LSE catalogues (Table 1). The stars selected are either IRAS point sources and or O, B and A supergiants at high galactic latitudes, according to MK types given in the literature. The sample is biased towards stars which show some post-AGB characteristic, i.e. positional coincidence with an IRAS point source with far-IR colours similar to post-AGB stars and PNe (van der Veen & Habing 1988; Pottasch et al. 1988), high galactic latitude or known spectral peculiarity, luminous O, B, and A spectral types, and emission lines in the spectrum. Our sample includes 29 stars, which are not IRAS sources so that we may be able to detect, post-AGB stars without dust shells, similar to BD+ 39 4926 (Kodaira 1973). We selected 38 stars from the LSS catalogue, 4 stars from LSE catalogue and two stars from LS catalogue. In the total selected sample of 44 stars only 15 stars are IRAS sources (Table 2, Figure 1).

3. Observations

Digital spectra of 44 selected (Table 1) southern candidates were obtained during 19th to 27th April 1994 using the spectrograph and 2d-Frutti two-dimensional photon counting detector on the 1m telescope of the Cerro Tololo Inter-American Observatory in Chile. The exposure times ranged from 10 minutes to 30 minutes. Because of limited observing time at our disposal we have observed the selected stars only once. The wavelength coverage is 3800Å to 5000Å, and judging from the comparison spectra, the resolution is about 3.5 Å. The data were extracted, wavelength calibrated, and normalized to the continuum with the standard IRAF software. Spectra of all the 44 stars are shown in Figure 2. Results of analysis of spectra of 40 IRAS sources obtained during the above mentioned observing dates were given in paper - I (Parthasarathy et al. 2000).

4. Analysis

4.1. Spectral classification

We have compared the spectra of our program stars with the spectra of standard OB stars (Walborn & Fitzpatrick 1990). Walborn and Fitzpatrick made a digital atlas of the spectra of OB stars which they observed with the same instrument, but at higher resolution than that described above. We found that smoothing the Walborn and Fitzpatrick spectra by 3.5 Å produced nearly identical looking spectra for the O9.5V star HD 37468, which we observed, and the Walborn and Fitzpatrick O9.5V standard HD 93027. The errors in the spectral atlas of Walborn and Fitzpatrick are of the order of 0.2 to 0.3 subtypes. Among the O-stars they could classify O9.5 and O9.7 and among B stars they could classify B0.5 and B0.7. Spectral types for non OB stars were estimated by comparison with the photographic atlas of Yamashita et al. (1978). The spectral types determined from the present investigation are given in Table 1. For non-OB stars we have also used the digital spectral atlases of Silva & Cornell (1992), Jacoby et al. (1984), and Pickles (1998), however these atlases are of much lower resolution than our spectra. The errors in our spectal types that we gave in Table 1 are of the order of 0.3 to 0.5 subtypes. For example we were able to distinguish spectral differences among B1, B2, and B3 stars. The letters e, f, p, and n by the side of spectral types in Table 1 are of standrard MKK notation. Letter "e" indicates emission line(s) in the spectrum, "f" indicates O-type star with emission lines, (f) indicates N III emission is present and the notation ((f)) signifies that in addition to strong He II 4686Å weak N III $\lambda\lambda$ 4634-4640-4642 emission is present (Walborn & Fitzpatrick 1990), "p" indicates peculiar, and "n" indicates broad lines. Spectra of all the stars listed in Table 1 are shown in Figure 2 starting with star no. 1 in Table 1 (top fisrt column of Figure 2) to star no. 44 (bottom of the second column of Figure 2). Notes on some of the objects is given in section 4.3.

4.2. Location of the IRAS sources in the IRAS colour-colour diagram

In our sample of stars there are only 15 IRAS sources and they are listed in Table 2. Their IRAS fluxes from SIMBAD are also listed in Table 2. The letter "L" on the side of some of the fluxes indicates that the error in the flux value is large. We have not listed the 100 micron flux in Table 2 for some of the objects as their 100 micron flux is not relaiable (see SIMBAD data base). In Figure 1 we show the location of the objects (fillled circles) listed in Table 2 in the IRAS colour-colour diagram (Pottasch et al. 1988). The location of the star LSS 207 is not shown in Figure 1 as its 60 micron flux quality is very low and therefore the 25 to 60 micron flux ratio is beyond the X-axis scale. The Figure 1 is adopted from the paper by (Pottasch et al. 1988). The 14 objects (Table 2) are in the region defined by PNe. PNe, PPNe and post-AGB supergiants have similar IRAS colours (Pottasch et al. 1988) and occupy the same region in the colour-colour diagram defined by the PNe (Figure 1). Most of the stars listed in Table 2

Table 1. Spectral types of LS, LSS and LSE stars based on our spectra

No.	Star	b	Sp.	New Sp.Type	m_V	comment
1	LSS 3169	-4.24	W(C)	pec.em.	13.2	PN [WC9]
2	LSS 3299	+3.99	WRh	pec.em.	11.9	PN [WC11]
3	LSS 207	-4.40	OB+	O6V((f))	10.9	Post-AGB ?
4	LSS 3888	-5.14	OB+	O6V((f))e	12.6	PN
5	LSS 827	+0.36	OB	O6Vn	9.2	O6:nne., in nebulosity
6	LSS 3119	+0.04	OB	O8Iaf	9.2	HD117797(Oe); O8.5
7	LSS 3418	-9.66	OB:(ce),lep,h	O9Iae	11.0	HD 141969; PN
8	LSE 67	-13.58	OB+	O9IIe	12.2	-29 15495, PN, post-AGB
9	LSS 1448	-0.03	OB+r	O9.5III	11.0	CD -55 3196
10	LSS 1947	-0.51	OB	O9.5V	10.1	HD 305599
11	LSS 4349	+3.89	OB	B0III	9.6	-22 4400, Herbig Ae-Be
12	LSS 2354	-1.55	OB-	B0V	9.6	HD 99898; B0.5V:, HII
13	LSS 1394	-8.23	OB+ce,h	B2:nep	10.5	CPD -64 1154, Post-AGB?
14	LSS 2241	-10.58	OB+	B1Ib	10.1	CD -71 730, Post-AGB
15	LSE 42	+14.59	OB+	B1Ib	12.7	post-AGB
16	LSS 1245	-6.57	OB	B1III-V	11.4	CD -56 2603
17	LSS 1021	-1.18	OBce,h	B1II-Vne	9.1	HD 69425; B1Vpe
18	LSS 968	+8.21	OB-	B1V	10.7	-17 2357
19	LSS 3434	-0.46	OBh	B1Vn	11.1	-53 6867, Herbig Ae-Be
20	LSS 1256	-6.28	OB+ce,le,h	B2ne	12.2	Post-AGB?
21	LSS 1341	-10.68	OB(ce)	B2ne	9.6	HDE 309784; Post-AGB
22	LSS 2429	+7.51	OB+h	B2:ne	12.7	Flat continuum; Post-AGB?
23	LSS 1276	+5.37	OB+h	B2:nep	9.8	HD80834; B5nne, post-AGB?
24	LSS 866	-5.94	OB-	B2III	8.5	-39 3775 = HD 65054
25	LSS 1263	+6.72	OB-	B2IIIn	10.1	-38 5410
26	LSVI+5 5	-2.09	OB	B2IIIn	7.8	+5 1279
27	LSS 1060	-6.20	OB+	B2III-V	12.7	
28	LSS 1367	+4.37	OB	B2III-Ve	12.0	CD -48 5103
29	LSS 327	-1.76	OB	B2V	12.2	
30	LSS 2832	+0.79	OB+	B2:V:	13.0	
31	LSS 1339	-7.34	OB-h	B2Ve	10.7	CPD -62 1290
32	LSS 1392	-5.96	OB+ce,le,h	B2Ve	10.7	HD 307467
33	LSS 1996	-9.91	OB	B2Ve	11.6	CPD -69 1417
34	LSS 1213	+1.90	OB-	B2Vp	9.7	CD -42 4819
35	LSS 1179	-1.59	A1Ia:h	B3Ibp	11.4	CD -46 4657, post-AGB
36	LSE 3	+12.26	OB+	B3IIIe	11.5	BD-18 4436, post-AGB
37	LSS 4560	-7.37	OB	B3IIIep	11.3	Hen 3 - 1557, Post-AGB
38	LSS 1222	-7.10	B7I-II	B9Iap	11.6	Post-AGB
39	LSS 1340	-3.19	A1II	A1II	11.4	PN, Binary Central Star
40	LSS 3309	+8.65	A5Iab	A3I	7.6	HD 133656, post-AGB
41	LSE 16	+8.88	OB+	A3I	12.0	LSS 4079, post-AGB
42	LSVI+10 15	9.99	F5I	F5Ia	8.1	+10 1470, post-AGB
43	LSS 1033	+7.49	OB:	F7V	13.5	
44	LSS 1120	+7.22	OB+	F7V	12.9	

Table 2. Stars which are IRAS sources

Star	IRAS	12μm (Jy)	25μm (Jy)	60μm (Jy)	100μm (Jy)
LSS 207	IRAS 07077-1825	0.80	6.66	0.40L	—
LSS 827	IRAS 07502-2618	8.49	69.32	183.30L	—
LSS 1179	IRAS 08487-4623	0.25L	0.91	2.12	—
LSS 1340	IRAS 09418-5703	0.42	4.88	6.40	—
LSS 2354	IRAS 11265-6239	1.37L	11.38	28.98L	—
LSS 3169	IRAS 13487-6608	1.19	9.16	11.75	—
LSS 3299	IRAS 14562-5406	92.41	310.50	176.60	71.30
LSS 3309	IRAS 15039-4806	0.25L	4.29	3.61	—
LSS 3418	IRAS 15513-6600	2.16	48.18	43.81	19.58
LSS 3434	IRAS 15543-5342	3.65	11.86	26.55L	—-
LSS 3888	IRAS 16577-5018	0.25L	1.05	1.99	—
LSS 4349	IRAS 17408-2204	1.61	13.28	33.60	44.18
LSS 4560	IRAS 17591-3731	0.35L	1.22	0.91	—
LSE 3	IRAS 17074-1845	0.50	12.20	5.66	3.47
LSVI +10 15	IRAS 07134+1005	24.51	116.70	50.13	18.72

(Figure 1) are classified as post-AGB objects (Table 1). The evolutionary status of LSS 827, LSS 2354, and LSS 4349 is not clear. An occasional H II region, or a nebula or a T Tau or Herbig Ae-Be star have IRAS colours similar to PNe and post-AGB objects (Pottasch et al. 1988). Notes on individual IRAS sources is given in the next section.

4.3. Notes on individual objects in Table 1

LSS 207 = IRAS 07077-1825

It may be a post-AGB star or a compact HII region. The far-IR (IRAS) colours are similar to PNe. It has a detached cold dust shell with a flux maximum at 25 microns. UBV photometric observations were made by Drilling (1991). BVRIJHK photometric observations were made by Fujii et al. (2002).

LSS 827 = IRAS 07502-2618 = CD -26 5115 = HD 64315

It is listed as an emission line and variable star V402 Pup. We find emission in the core of Hβ. We also find emission lines at 4934Å and 5009Å which may be of circumstellar or nebular origin. In the Michigan spectral classification catalogue the spectral type of LSS 827 is given as A1(Ia)p. Spectral type variations appear to be present. It may be an early type shell star. It is in the region of the open cluster NGC 2467 and is involved in nebulosity. Cluster membership is not certain.

LSS 1021

The H and HeI lines are filled in. It is listed as an emission line star (MWC 855).

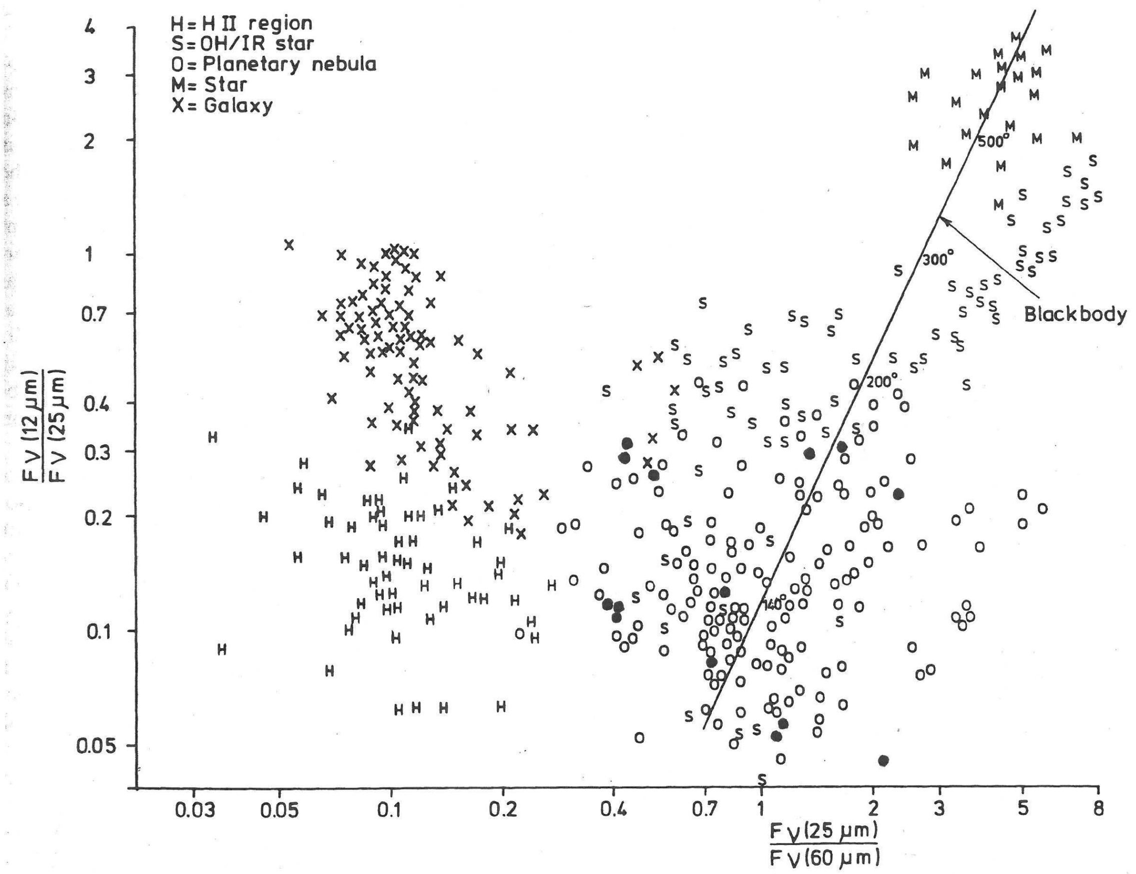

Fig. 1. IRAS colour-colour diagram adopted from the paper by Pottasch et al. (1988). The filled circles are the objects listed in Table 2

LSS 1179 = IRAS 08487-4623

Preite-Martinez (1988) classified it as a new possible PN on the basis of IRAS colours. In 1971 it was classified as a A1Ia star (Reed & Beatty 1995). However the present spectrum is clearly shows that of B3Ibp star. The FeII lines are weak. The HeI lines are broad with emission in the cores. The spectrum indicates the presence of a shell. It may be a post-AGB star evolving rapidly to the early stages of a PN, or it is an early type shell star.

LSS 1222

It was earlier classified as B7I-II star (Reed & Beatty 1995). The spectrum suggests that it is a metal-poor B9Iap star. High galactic latitude and a metal-poor supergiant type spectrum suggest that it may be a post-AGB star similar to HR 4049 (Takeda et al. 2002) and BD+39 4926 (Kodaira 1973). It is not an IRAS source, so is similar to the post-AGB star

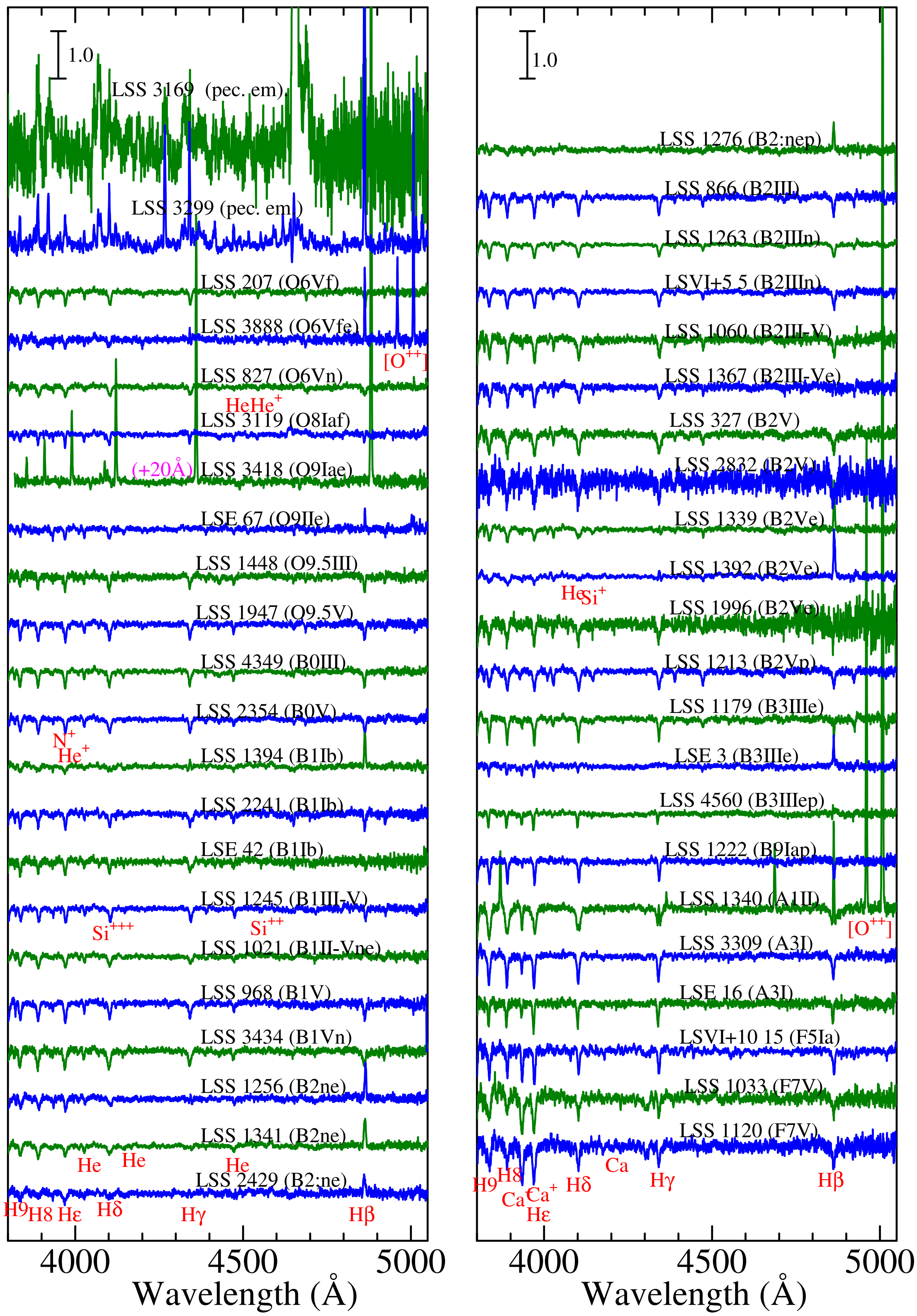

Fig. 2. Specra of 44 stars (Table 1) (normalized with respect to the continuum level), based on which we conducted spectral classifications. Each of the spectra are arranged according the spectral type, and shifted by 1.0 relative to the adjacent ones. Positions of lines important for spectral classifications (e.g., Balmer lines; He I 4026, 4121, 4144, 4471; He II 4009, 4551; N II 3995; [O III] 4959/5007; Si II 4128–30; Si III 4552; Si IV 4089; Ca I 4227; Ca II 3933/3968) are indicated in the figure. Regarding LSS 3418 showing conspicuous emissions in Balmer lines, the wavelength scale is shifted by +20 Å in order to avoid overlapping with the emission spectra of other stars. Note also the srong [O III] emission in LSS 1340.

BD+39 4926. Such stars can be termed as naked post-AGB stars.

LSS 1245 = CD -56 2603

H and HeI lines are partly filled in by emission.

LSS 1256

Hβ and Hγ are in emission. The higher members of the Balmer series also appear to be affected by emission.

LSS 1276 = HD 80834

Hβ and Hγ are in emission. Other higher members of the Balmer series appear to be filled in by emission. It is classified as a variable star QQ Vel.

LSS 1339 = CPD -62 1290

Balmer lines up to Hδ are in emission.

LSS 1340 = IRAS 09418-5703 (PN G 279.6-03.1)(He2-36)

It is a PN central star. The central star is a binary with a A1II (Méndez 1978) companion. He II 4686Å is present indicating that the central star is of very high temperature (Méndez 1978). Our spectrum confirms the presence of the A1II star companion to the central star.

LSS 1341 = HD 309784

Hβ and Hγ are in emission. HeI lines also appear to be affected by emission. Many of the H and HeI lines seems to have emission in the cores. High galatic latitude and the appearence of the spectrum suggests that it may not be a massive pop. I OB star. It may be a post-AGB star.

LSS 1367 = CD -48 5103

Hβ and Hγ lines appear to be affected by emission.

LSS 1392 = HD 307467

Emission in Balmer lines.

LSS 1394 = Hen3-356

Balmer lines in emission.

LSS 1996

Hβ and Hγ lines may be affected by emission.

LSS 2241

We find it to be a high galactic latitude B1Ib star. It may be a post-AGB star similar to LSII +34 26.

LSS 2354 = IRAS 11265-6239 = V1087 Cen

H and He lines are affected by emission. They appear to be partially filled in. The far-IR colours are similar to PNe. The presence of circumstellar dust and B0V spectral type, and low galactic latitude indicates that it may be a compact HII region.

LSS 2429

Hβ and Hγ are in emission. Other members of the Balmer series also appear to be affected by emission. The spectrum is similar to that of LSS 1394.

LSS 3119 = HD 117797

The NIII lines are in emission. Gomez & Niemela (1987) detected strong carbon lines. They have estimated the mass-loss rate.

LSS 3169 = IRAS 13487-6608 = He2-99

It is a planetary nebula. We classify the central star spectrum to be [WC9] which is in agreement with the earlier classification (Acker et al. 1992; Acker & Neiner 2003).

LSS 3299 = IRAS 14562-5406 = He3-1044

It is a planetary nebula. We classify the central star spectrum to be [WC11] which is in agreement with the earlier classification (Acker et al. 1992; Acker & Neiner 2003).

LSS 3309 = HD 133656 = IRAS 15039-4806

Earlier spectral classification of this star was by Van Winckel (1997) It is an IRAS source with far-IR colours very similar to PNe. Van Winckel (1997) determined the chemical composition from an analysis of high resolution spectra. They find it to be metal-poor. We find the spectral type to be A3I. Monier & Parthasarathy (1998) analysed the UV (IUE) spectra of this star. They find E(B-V) = 0.32, Teff = 8750K, log g = 2.5 and [Fe/H] = -1.0. The A3I spectral type derived by us is in agreement with the above parameters. High galactic latitude, presence of circumstellar dust with colours similar to PNe and underabundance of metals clearly suggest that it is a post-AGB star.

LSS 3418 = IRAS 15513-6600 = He2-138 = PN G320.1-09.6

It is a planetary nebula (Acker et al. 1992). We classify the spectrum of the post-AGB central star to be O9Iae.

LSS 3434 = IRAS 15543-5342 = CPD -53 6867

The presence of circumstellar dust, low galactic latitude and B1Vn spectral type suggest that it may be a Herbig Ae/Be type star.

LSS 3888 = IRAS 16577-5018 = He2-187 = PN G 337.5-05.1

It is a planetary nebula (Acker et al. 1992; Kohoutek 2001). The spectrum of the central star is classified for the first time. We find the spectral type of the central star to be O6V((f))e.

LSS 4349 = SAO 185668 = IRAS 17408-2204

Malfait et al. (1998) classified it as a Herbig Ae/Be star. The IRAS far-IR colours indicate a cold circumstellar dust shell with high fluxes at 60 and 100 microns.

LSS 4560 = IRAS 17591-3731 = HD 324802

The far-IR (IRAS) colours are similar to PNe. We find that Hβ is in emission. H and HeI lines are partially filled in. The far-IR colours, high galactic latitude and B3IIIep spectral type indicate that it is most likely a post-AGB star. UBV photometric observations were made by Drilling (1991).

LSE 3 = IRAS 17074-1845 = Hen 3 - 1347

IRAS colours, high galatic latitude, and spectrum indicate that it is most likely a hot post-AGB star (Gauba & Parthasarathy 2003; Umana et al. 2004).

LSE 16 = LSS 4079

A3I spectral type and high galactic latitude indicate that it may be a post-AGB star. UBV photometric observations were obtained by Drilling (1991).

LSE 42

Hβ is filled in. The B1Ib spectral type and high galactic latitude indicate that it may be a post-AGB star. It may not be a massive pop. I B star.

LSE 67 = CD -29 15495

It is a high galactic latitude OB+ star (Drilling & Bergeron 1995). We find weak emission around [O III] 5007Å and Hβ in emission. Based on these emission lines, we conclude that it may be a new low excitation planetary nebula. The spectral type of the central star is found to be O9IIe.

LS VI + 05 5 = HD 46106

Member (115) of cluster NGC 2244 (Ogura & Ishida 1981)

LS VI +10 15 = IRAS 07134+1005 = HD 56126

Earlier spectral classification of this star is given in (Reed & Beatty 1995) It is a well known and well studied post-AGB star. High resolution spectra of this star was analysed by Parthasarathy et al. (1992); Van Winckel & Reyniers (2000); Klochkova & Chentsov (2007). It is metal-poor ([Fe/H] = -1.0) and shows over abundance of carbon and s-process elements. It is a post-AGB star with 21-micron emission feature (Kwok 1993).

5. Discussion and Conclusions

The presence of circumstellar dust with far-IR colours similar to PNe, high galactic latitude, OB supergiant type spectrum, and emission in the Balmer lines are some of the characteristics of hot post-AGB stars. In the sample of observed stars we found a few cases of B type dwarfs with Hβ emission. The presence of circumstellar material around Be dwarfs indicates that they may be related to other Be stars, shell stars or Herbig Ae/Be stars. In Table 1 we have a few other objects which are not known to be post-AGB stars. They were included in the observing program as some of them have IRAS colours overlapping with the IRAS colours of some known post-AGB stars. The comments given in Table 1 for some of the stars are from the OB star catalogues and SIMBAD data base. For more information on previous spectral classification, notes and comments etc. refer to OB star catalogues and SIMBAD data base. The m_V given in Table 1 is from the SIMBAD data base.

New spectral types for 44 O, B and A stars in the LS, LSS, and LSE catalogs have revealed several new hot (OBA supergiant) post-AGB candidates on the basis of either coincidence with IRAS point sources or high galactic latitude. None of these objects shows any evidence of a changing spectral type, but we plan to continue our monitoring program. Some of the post-AGB candidates we detected in our sample are not associated with an IRAS source, indicating they do not have dust shells. These are low mass objects and their evolution in the HR diagram from the tip of the AGB is rather very slow and by the time they evolve to A, B, O post-AGB spectral type, the dust shells seems to have disappeared and they may never appear as planetary nebulae, hence they can be called naked post-AGB stars (e.g. BD +39 4926). Mutliwavelength study of post-AGB candidates discussed in this paper is needed to further understand their chemical composition and evolutionary stage. Some of the post-AGB candidates given in Table 1 may show light variations similar to the high galactic latitude hot post-AGB stars LS II +34 26 and SAO 85766 (Arkhipova et al. 2007).

All the spectral data used in this study are given in the digital form in electronic table E, which is available at the PASJ web site.

6. Acknowledgements

This research was supported in part by a grant from the National Science Foundation (NSF) (AST-9819835) to JSD. MP is very thankful to Prof. Shoken Miyama and Prof. Ramanath Cowsik for their kind encouragement and support, JV participated in the work during her stay at IUCAA. We are thankful to Dr. Shashikiran Ganesh for his help in converting the data into fits files. We are thankful to the referee for helpful comments.

References

Acker, A., Marcout, J., Ochsenbein, F., Stenholm, B., & Tylenda, R. 1992, Strasbourg - ESO catalogue of galactic planetary nebulae. Part 1; Part 2, ed. Acker, A., Marcout, J., Ochsenbein, F., Stenholm, B., & Tylenda, R.

Acker, A.,& Neiner, C. 2003, A&A, 403, 659

Arkhipova, V.P., Esipov, V.F., Ikonnikova, N.P., et al. 2007, Astronomy Letters, 33, 604

Bobrowsky, M., Sahu, K.C., Parthasarathy, M., & Garcia-Lario, P., 1998, Nature, 392, 469

Conlon, E.S., Dufton, P.L., McCausland, R.J.H., & Keenan, F.P., 1993, ApJ 408, 593

Drilling, J. S. 1991, ApJS, 76, 1033

Drilling, J. S. 1994, in ASP Conference Series, Vol. 60, The MK Process at 50 Years: A Powerful Tool for Astrophysical Insight, ed. C. J. Corbally, R. O. Gray, & R. F. Garrison, 57

Drilling, J. S. & Bergeron, L. E. 1995, PASP, 107, 846

Fujii, T., Nakada, Y., & Parthasarathy, M. 2002, A&A, 385, 884

Garcia-Lario, P., Parthasarathy, M., de Martino, D., et al.1997, A&A 326, 1103

Gauba, G., & Parthasarathy, M. 2003, A&A, 407, 1007

Gomez, D. O., & Niemela, V. S. 1987, RMxAA, 14, 293

Hardrop, J., Rohlfs, K., Slettebak, A., & Stock, J. 1959, Luminous Stars in the Northern Milky-Way (Hamburg, Bergedorf)

Jacoby, G. H., Hunter, D. A., & Christian, C. A. 1984, ApJS, 56, 257

Klochkova, V. G., & Chentsov, Ye. L., 2007, ARep, 51, 994

Kodaira, K. 1973, A&A, 22, 273

Kohoutek, L. 2001, A&A, 378, 843

Kwok, S. 1993, ARA&A, 31, 63

Malfait, K., Bogaert, E., & Waelkens, C. 1998, A&A, 331, 211

McCausland, R.J.H., Conlon, E.S., Dufton, P.L., & Keenan,F.P., 1992, ApJ, 394, 298

Méndez, R. H. 1978, MNRAS, 185, 647

Moehler, S., & Heber, U., 1998, A&A, 335, 985

Monier, R. & Parthasarathy, M. 1998, Ap&SS, 255, 487

Ogura, K., & Ishida, K. 1981, PASJ, 33, 149

Parthasarathy, M. 1993, ApJ, 414, L109

Parthasarathy, M., Garcia-Lario, P., de Martino, D., et al. 1995, A&A, 300, L25

Parthasarathy, M., Garcia-Lario, P., Pottasch, S. R., et al. 1993, A&A, 267, L19

Parthasarathy, M., Garcia-Lario, P., Pottasch, S. R., 1992, A&A, 264, 159

Parthasarathy, M. & Pottasch, S. R. 1986, A&A, 154, L16

Parthasarathy, M. & Pottasch, S. R. 1989, A&A, 225, 521

Parthasarathy, M., Vijapurkar, J., & Drilling, J. S. 2000, A&AS, 145, 269

Pickles, A. J., 1998, PASP, 110, 863

Pottasch, S. R. & Parthasarathy, M. 1988, A&A, 192, 182

Pottasch, S. R., Bignell, C., Olling, R., & Zijltra, A. A., 1988, A&A, 205, 248

Preite-Martinez, A. 1988, A&AS, 76, 317

Reed,B. C. & Beatty, A. E. 1995, ApJS, 97, 189

Silva, D. R., & Cornell, M. E. 1992, ApJS, 81, 865

Smith, V.V., & Lambert, D.L., 1994, ApJ, 424, L123

Stephenson, C. B. & Sanduleak, N. 1971, Publications of the Warner & Swasey Observatory, 1, 1

Takeda, Y., Parthasarathy, M., Aoki, W., et al. 2002, PASJ, 54, 765

Turner, D.G., & Drilling, J.S., 1984, PASP, 94, 789

Umana, G., Cerrigone, L., Trigilio, C., et al. 2004, A&A, 428, 121

van der Veen, W.E.C.J., & Habing, H.J. 1988, A&A, 194, 125

Van Winckel, H. 2003, ARA&A, 41, 391

Van Winckel, H. 1997, A&A, 319, 561

Van Winckel, H., & Reyniers, M. 2000, A&A, 264,159

Vijapurkar, J., Drilling, J.S., Parthasarathy, M., 1997, AJ, 114, 1573

Vijapurkar, J., Parthasarathy, M ., Drilling, J.S., 1998, BASI, 26, 497

Volk, K.M., & Kwok, S., 1989, ApJ, 342, 345

Walborn, N. R. & Fitzpatrick, E. L. 1990, PASP, 102, 379

Yamashita, Y., Nariai, K., & Norimoto, Y. 1978, An Atlas of Representative Stellar Spectra (University of Tokyo Press, Tokyo)